SpW Application from JAXA

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SpaceWire Working Group Meeting 6

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Contents

• SpW application to robots
  • current robot: asteroid rover
  • future robot project

• Space Cube series
  • CPU box with SpW I/Fs working by T-Engine realtime kernel
  • Space Cube I
  • Space Cube II

• SpW demonstration by Space Cube II
MINERVA

- Mlcro/Nano Experimental Robot Vehicle for Asteroid
- Installed in HAYABUSA spacecraft

- should have become the first asteroid surface explorer
  - deployed to the asteroid surface on 12 Nov, 2005
  - did not land on the asteroid surface
  - became a solar orbiting satellite

- Very small and light-weighted
  - mass: 591[g]
  - size: diameter 120[mm] x height 100[mm]
  - can be applicable to a record in Guiness Book?

- Technical experimental rover
  - hopper
  - autonomous exploration
HAYABUSA Mission

• sample return mission to asteroid
  • size: 1000 x 1600 x H1000[mm]
  • mass: 512[kg] (with fuel), 380[kg] (without fuel)

• launched on 9 May, 2003.
• rendezvous at ITOKAWA in Sep, 2005.
• touchdowns to ITOKAWA in Nov, 2005.
• still on the asteroid orbit till 2007.
• will be back to the Earth in 2010.

• target asteroid “ITOKAWA”
  • size: 540 x 250 x 220[m]
  • very weak surface gravity
    gravity: $4 \times 10^{-6} \sim 2 \times 10^{-5}$[G]
    escape velocity: $16 \sim 24$[cm/s]
<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>size</td>
<td>hexadecagonal pole (diameter: 120[mm], height: 100[mm])</td>
</tr>
<tr>
<td>mass</td>
<td>591[g]</td>
</tr>
<tr>
<td>onboard computer</td>
<td>32bit RISC (@10[MIPS]) ROM: 512[kB], RAM: 2[MB], FlashROM: 2[MB]</td>
</tr>
<tr>
<td>OS</td>
<td>iTRON (realtime OS)</td>
</tr>
<tr>
<td>actuators</td>
<td>DC motor ( \times 2 )</td>
</tr>
<tr>
<td>mobile system</td>
<td>hopping (max 9[cm/s]@rigid surface)</td>
</tr>
<tr>
<td>power supply</td>
<td>solar cells: max: 2.2[W] @1[AU] from Sun capacitors: 5[V], 25[F]</td>
</tr>
<tr>
<td>communication</td>
<td>9,600[bps] (half duplex, max distance: 20[km])</td>
</tr>
<tr>
<td>sensor(navigation)</td>
<td>photo diode ( \times 6 ), thermometer ( \times 4 )</td>
</tr>
<tr>
<td>sensor(science)</td>
<td>color CCD camera ( \times 3 ), thermometer ( \times 6 )</td>
</tr>
<tr>
<td>temperature range</td>
<td>-50 ( \sim ) +80[C]</td>
</tr>
<tr>
<td>life</td>
<td>3[asteroid days] (1[asteroid day]=12.15[h])</td>
</tr>
</tbody>
</table>
MINERVA Operation

• Deployed on 12 Nov, 2006 by the command from the ground.

• But ...
  • MINERVA did not arrive at the asteroid due to the unexpectedly large velocity of Hayabusa relative to the asteroid.
  • MINERVA became a Solar-orbiting satellite.
  • Telemetry link between MINERVA and Hayabusa was established for 13 hours after the deployment
  • After the telemetry link was over, no one knows what MINERVA became.
  • The last telemetry showed MINERVA was very healthy. It may be active now.
MINERVA is a hopper.

Microgravity experiment using a drop tower
• MINERVA captured Hayabusa after the deployment.
• It was the first picture that the spacecraft in the deep space ($300 \times 10^6$ km away) was directly shot from the other spacecraft.

The area is not transmitted because the area with no features was not stored.
MINERVA obtained data (2)

- The voltage of the battery
- PDs measuring the incoming light (6ch)
- Temperature inside (4ch)
- Temperature outside (6ch)
MINERVA pictures by HAYABUSA

212[sec] after deployment

250[sec]

300[sec]

○ cover ○ MINERVA
Future Plan of Robotics: Small Space Robot Probe

- weighted in a few kilograms: Pico-sized S/C
- ex.
  - Another asteroid surface rover (MINERVA-II,III,IV,V ...)
  - Small flyby S/C to asteroids and comets
  - Earth orbiting robot satellite
    (such as autonomous rendezvous)

- Network bus is not necessary. But for making various probes fast and cheaply, SpW may be one solution for sensor I/F
  - CPU modules are always identical.
  - Sensors are connected by SpW I/F to the CPU module.
  - Sensors are different in mission to mission.
  - Power and thermal controllers are adjusted in mission to mission.
Next Generation MINERVA

- CPU
- RAM
- FlashROM
- RF module
- serial

Local bus:
- FPGA
- SpW
- SpW
- ... (SpW)

CPU module:
- motor
- sensors
- camera, thermometer, seismometer
Future Plan of Robotics: Lunar Rover

• weighted in 20-50[kg]

• Network bus is essential for the data handling of this class of S/C.
SpaceCube I

Small CPU box provided with three SpaceWire I/Fs based on TeaCube (a commercial product)

Specifications
- size: 52[mm] × 52[mm] × 55[mm]
- mass: 220[g] (not including a power supply)
- CPU: VR5500CPU (clock: 200MHz)
- OS: T-Engine (successor of iTRON)
  - Linux
- color: black

- I/F:
  - SpaceWire × 3 ports
  - USB × 2 ports
  - Compact Flash
  - VGA (display)
  - RS-232C serial port
  - LAN
  - Headphone, Microphone

Notice
- Not guaranteed a use in space.
- You can make a presentation and listen to music.
SpaceCube II

- Space-proof CPU board provided with SpaceWire I/Fs
- Not a cube. Looks like a M*c Mini

*M*c Mini: 165mm x 165mm x 51mm, 1.3kg
SpaceCube II

Specifications
• size: 148mm x 148mm
• height: 40mm (stacked by CPU board and IO board)
• CPU: radiation-proof MIPS based 64bit CPU developed by JAXA
  (processing speed: max of 200[MIPS])
• power: 10[W]
• OS: T-Engine
• I/F
  • SpaceWire I/F × 6 ports
  • LAN
  • serial: RS232c × 2 ports, RS422 × 2 ports

Notice
• will be usable in space.
• You can neither make a presentation nor listen to music

• Current Status
  • Prototype model was fabricated
  • Installation of OS is being conducted and will be completed in August
Demonstration by Piggyback Satellite

- Launch: Summer, 2008
- Vehicle: Japanese H-IIA rocket
- Main satellite: GOSAT (1650[kg], Earth observing satellite)
  - There is a large extra cargo space
- Orbit: Sun-synchronous polar orbit (altitude: 666[km])

Piggyback satellites to be launched

1. Engineering small satellite by JAXA
   - 100[kg] class
   - SpaceCube II will be installed

2. Small satellites from the general public
   - Public announcement of call for satellites was published on 10/May/2006 by JAXA only in Japanese.
   - Weight: 1 - 50[kg]
   - Application due: Aug.2006
JAXA Engineering
Piggyback Small Satellite

- New technical functions are tested and demonstrated by the satellite based on a matured components.
- SWIM (SpaceWire Interface Module) composed of the SpaceCube II and the sensor sub-module
JAXA Engineering Satellite Configuration

- Actuators
- Sensors
- RF module
- Main CPU
- Power controller
- Heater controller
- Attitude controller
- Technical modules to be tested
- Mission CPU
- SWIM
- SpaceCube II

- S/C bus-part
- Traditional data bus
- JAXA-developed radiation hard CPU is also used.
- Serial
- Other modules

SpaceCube II is used in SWIM.
SWIM (SpaceWire Interface Module)

- size: 200mm x 200mm x 150mm
- mass: 5.0[kg]
- power: 25[W] (including loss by DC-DC)

What SWIM do?
- Obtained data by a couple of sensors are transmitted by SpW to SpaceCube II.
SWIM Configuration

• Sensors
  • two Gravitational wave detector
  • measurement of environment

• Routing
  • TBD

Mission CPU

command

serial port

RS422

telemetry

CPU

SpW I/F

Space Cube II

SpW I/F

SpW I/F

SpW I/F

SpW I/F

SpW I/F

other sensor

other sensor

SpW I/F
Summary

- Future rover project in Japan may use SpW
  - as a sensor I/F in Pico-sized small probes.
  - as a main databus in Lunar rovers.

- Space Cube I (CPU box with SpW I/Fs)
  Use in space is not guaranteed.
- Space Cube II is being developed.
  It can be used in Space.

- We are planning to demonstrate SpW in space
  by a piggyback satellite launched in 2008
  including Space Cube II
Proceed to Prof. Nomachi